

Nantucket Harbor Water Quality Synopsis
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Introduction

Nantucket Harbor has an approximate surface area of 5,254 acres. The harbor drainage basin is approximately 5,340 acres in size. Water quality has been monitored in Nantucket Harbor since 1990. Water quality in Nantucket Harbor has declined over time.

There have been serious declines in water quality in all coastal communities due to nutrient overloading. Nutrients are required for the health of all ecosystems. Coastal ecosystems have the capacity to assimilate some level of nutrient input without major changes in the ecological health. It is the excessive inputs of nutrients from natural processes and from anthropogenic (man made) pressures that cause ecosystem damage.

As nitrogen and phosphorus concentrations increase, the natural eutrophication process is accelerated. This process results in excessive aquatic plant growth, particularly in poorly flushed, shallow coastal embayments. As this over abundant plant growth dies, its decomposition uses up the available dissolved oxygen and creates anoxic conditions. The continued addition of nutrients and acceleration of plant growth leads to further decomposition by anaerobic bacteria (bacteria that don't require oxygen). The result is an embayment bottom coated with an organic mud residue (i.e. Wauwinet, Polpis, Quaise, Pocomo flats) and a habitat, once desirable for shellfish and finfish, now unsuitable for spawning and growth. If the water quality degrades to this point, aquatic life in the embayment is substantially diminished.

During the years of 1999 to 2002, the Marine and Coastal Resource Department biologists, Tracy Curley and Keith Conant, gathered nutrient information for Nantucket harbor and its' watershed drainage basin. Harbor sampling includes temperature, dissolved oxygen, salinity, water transparency, water quality constituents (nitrogen and phosphorus), and phytoplankton. The drainage basin sampling measured water flow and water quality constituents in nine streams identified by Northeast Aquatic Research which flow into Nantucket Harbor. The stations are as follows: **station 1 Mooring Field, station 2 Quaise Basin, station 3 Head of Harbor, station 4 Nantucket Sound, station 5 Polpis West, and station 6 Polpis East.** Nine streams, which extend from Wauwinet to the Life Saving Station, are sampled.

Neil Churchill, the Division of Marine Fisheries, provided historical shellfish closure information. The first closure on record for Nantucket Harbor was on January 15, 1932 by the State of Public Health. This closure was a line drawn from Brant Point to the northeasterly extremity of Swain's Wharf. On November 27, 1974 a sewer break caused the State of Public Health to close "all waters, flats, tributaries and shellfish areas of Nantucket Harbor inside of an imaginary line drawn from the northern most tip of Nantucket Cliffs in an easterly direction to easternmost tip of Coatue Point. It reopened on 12/3/74. On January 12, 1981 DEQE closed Nantucket harbor due to a sewer break. This closure was a line drawn across the tip of the two jetties and a line drawn from Second Point Southerly to Abrams Point. It reopened on January 29, 1981.

On April 16, 1982 another closure due to sewer line break. This time a line was drawn across the jetties and another line from Second Point southerly to Shimmo Point and east of a line Drawn from Bass Point to Pocomo Point excluding Polpis Harbor. This closure reopened on April 26, 1982. On January 25, 1984, DEQE closed Brant Point to the northeasterly extremity of Swain's Wharf. This became a permanent closure. On December 14, 1989, the DMF closed Brant Point to the northeasterly extremity of Nantucket Shipyard on the Washington Street Extention.

Except for closures due to storms and hurricanes no there was no change until October 19, 2001 when the DMF closed most of the harbor for 5 days. And on January 8, 2001 the DMF put into place the new closure from Brant Point to Boston Avenue.

For Polpis Harbor, the first closure other than a hurricane was on June 13, 1994. The DMF closed all the Polpis Harbor. Due to the intense sampling efforts of Tracey Mayhew, Nantucket Health Department, and Tracy Curley, Nantucket Shellfish and Marine Department, on August 25, 1995, the DMF reduced the closure to the lower section of West Polpis. And October 19, 2001 the DMF closed all of Polpis Harbor until further notice as a result of elevated fecal coliforms. Fecal coliforms are used as an indicator for potential viruses and bacteria in water rather than the pathogens themselves. The primary health concern related to the harvest ability of shellfish is that pathogens found in human fecal matter may contribute to widespread disease as a result of the consumption of raw shellfish contaminated by human fecal matter. These diseases include, but are not limited to, dysentery, typhoid, cholera, and hepatitis. The most common serious ailment is acute gastroenteritis. Additional concerns relate to ingestion by humans while swimming or otherwise using these waters.

Organic rich human waste has the potential to depress oxygen levels as they decay in the marine environment. Biological oxygen demand (BOD) is a measure of the dissolved oxygen required to decompose the organic matter in the water by aerobic processes. When the loading of organic matter increases, the BOD increases and there is a consequent reduction in the dissolved oxygen available for fish.

During the summer, anoxic and hypoxic pockets occur as temperature and oxygen separates the water column. Nutrient inputs from the watershed as well as internal recycling during low oxygen event upset the natural water chemistry balance inside the harbor. Increased nutrient concentrations change the physical environment for phytoplankton, macroalgae and fish populations.

Temperature

The temperature of water in the harbor varies slightly from basin to basin (horizontally) but remains relatively consistent from surface to bottom. There is more temperature variation inside Nantucket Harbor than in Nantucket Sound. The Sound is colder than the harbor during the spring and summer but warmer than the harbor in the fall and winter. The Sound is very large and loses heat to the atmosphere more slowly than the smaller harbor embayment. Conversely, the harbor will heat faster in sheltered areas and at the water surface. Temperature decreases with depth. The greatest difference water temperature occurs between the mooring field and the head of the harbor in water below 12 ft during the summer. This indicates that water does separate from the top to bottom during high temperatures in deep water.

Salinity

Salinity is the measurement of the amount of salt dissolved in water and usually is expressed in parts per thousand (ppt). Seawater can range from 24ppt to 36ppt depending upon freshwater inputs, evaporation, and circulation. Saltwater is more dense than freshwater and will sit on the bottom. Density is generally inversely related to temperature. As the water temperature decreases, the water becomes denser. As water separates, dissolved oxygen can be used up at certain depths if not replaced. If the salinity is the same from top to bottom, dissolved oxygen can pass freely between depths or layers of water.

The harbor salinity ranged from 30.4 ppt to 32.9 ppt for 2001. Salinity was stable from site to site. Site 1 (mooring field) was well mixed having very little variation from surface to bottom water. Site 2 (Quaise) had slightly less saline water at the surface in January (ice formation) and slightly more dense water on the bottom. Polpis Harbor may influence the slight (0.9ppt) salinity change from surface to bottom. Although Wauwinet and Quaise are similar in water depth, Wauwinet had less salinity variation within the water column (surface to bottom) than Quaise. This is most probably due to the Polpis Harbor influence on the Quaise Basin. Site 4 (Nantucket Sound) was uniform for all sample dates. Sites 5 and 6 (Polpis Harbor) had the lowest salinity due to size, depth, groundwater input and surface runoff. There was very little difference in salinity from surface to bottom due to the wind mixing the shallow basin of Polpis Harbor.

Shellfish commonly harvested in Nantucket Harbor have a wide salinity range in which they can flourish. Shellfish are present in various parts of the harbor according to their individual requirements. Although these shellfish can survive in a wide salinity range, all shellfish have a smaller salinity band in which they can grow and reproduce. Slight changes in salinity will dictate reproductive success while large fluctuations in salinity permit the shellfish to live but not reproduce. Oysters can survive in a salinity range of 5ppt to

30ppt. Oysters can live in marginal conditions; however, growth and gonad development are affected outside the normal salinity range. Predators are generally found in salinities greater than 10ppt. Soft shell clams are found in salinity range 5ppt to 33ppt. Soft shell clams grow best at the middle to upper end of this range. Quahogs and bay scallops grow best in a salinity range of 24ppt to 30ppt.

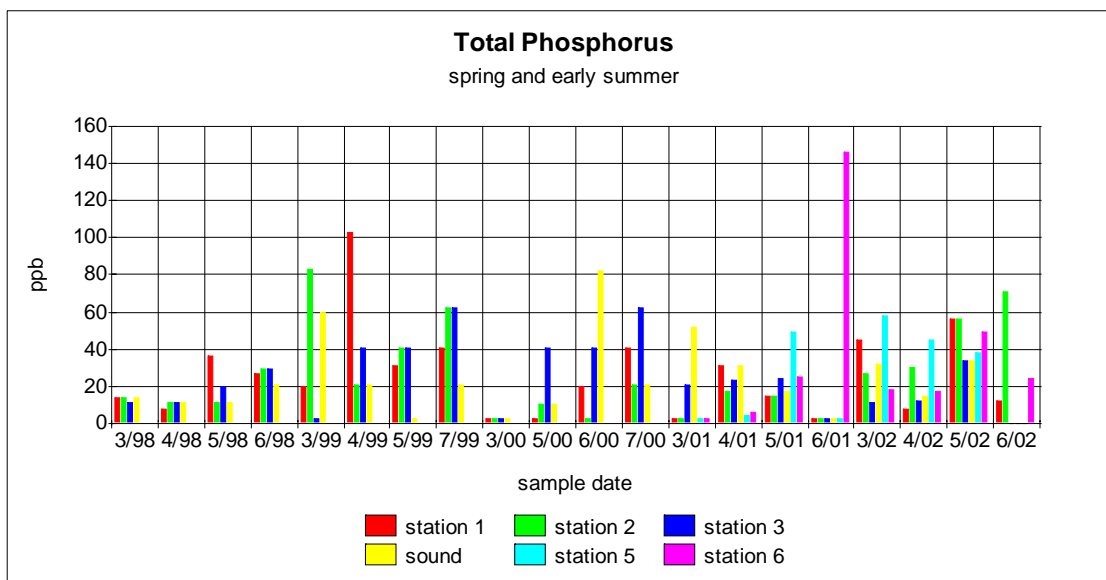
Dissolved oxygen:

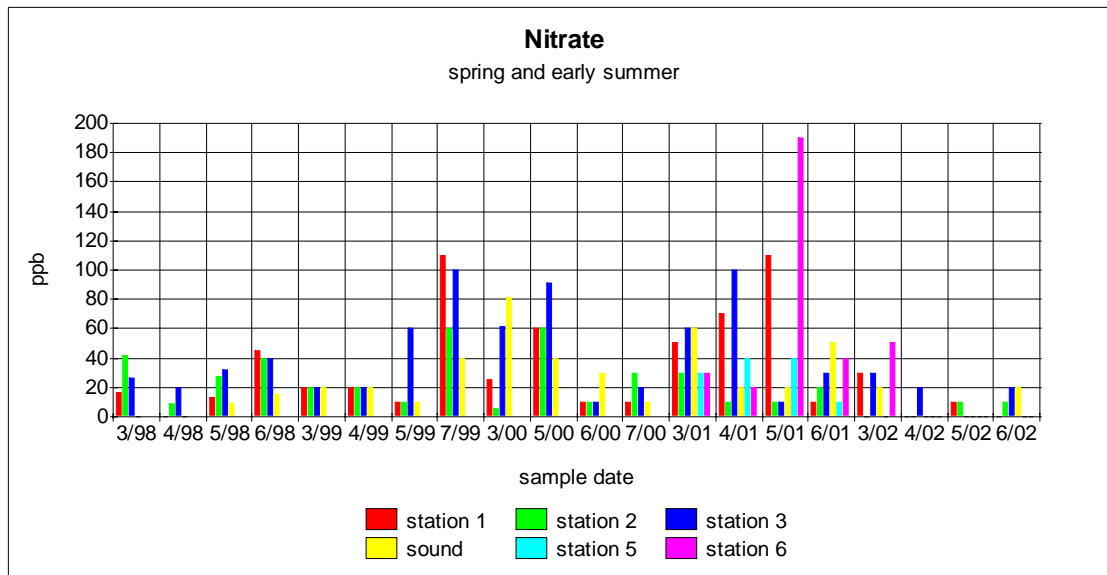
Shallow waters containing shellfish have sufficient dissolved oxygen to meet the requirements of the biotic community. An exception to this may occur when large masses of decaying vegetation accumulate on the bottom. The decaying process removes dissolved oxygen while increasing the amount of carbon dioxide in the water. Low oxygen concentrations may cause reduced growth or suffocation of the biotic community as well as shellfish. High concentrations of carbon dioxide can increase the acidity of the water. This change in water chemistry may have an adverse affect on the shellfish. Shell growth is impaired under acidic conditions, particularly shells located within sediments. Prolonged periods of “acid water” will cause dissolution of the calcium carbonate shell.

On average in 2001, dissolved oxygen concentrations in the harbor were slightly below Nantucket Sound. Dissolved oxygen concentrations were higher in the winter and fall due to cooler water temperatures. During January, February, and March, dissolved oxygen was super saturated in the water column. As the water temperature warmed in the spring and summer, dissolved oxygen was lost in the bottom layer of water. Generally in the Head of Harbor, the bottom layer of water reaches anoxia during July and August. During hypoxic (<5mg/l) and anoxic (<1mg/l) conditions, nutrients are released from the sediment into the water column. Generally at least 50 acres are exposed to hypoxic conditions each summer. Dissolved oxygen begins to increase late fall and continues to increase throughout the winter as water temperature cools.

Phytoplankton and Water Clarity

The harbor experiences a seasonal cycling of productivity. Productivity is a measurement of the concentration of phytoplankton in the water column. Two types of phytoplankton are generally used to gage the condition of the water, dinoflagellates and diatoms. Dinoflagellates are associated with high nitrate and phosphorus concentrations (summer). Diatoms are associated with certain nitrate concentration (winter).





When the nitrogen: phosphorus ratio is altered either by land or sea inputs, the phytoplankton species will shift in dominance. The phytoplankton type and availability can dictate the reproductive success of the bay scallop. Bay scallops feed on diatoms including suspended bacteria and detritus. The reproductive cycle of the bay scallop is correlated to peak phytoplankton concentrations in the water column. The type and size of the phytoplankton are important to the size and age of the scallop. Young scallop gills are very small and therefore require smaller diatoms (i.e. *Chaetoceros*) to eat. As the scallop ages, the scallops diet becomes more versatile as the scallop can filter larger diatoms (i.e. *Conscindodiscus*) through its mature gill structure. Dinoflagellates appear when the water temperature is warm and nutrients are abundant. Scallops do not eat dinoflagellates. As more dinoflagellates appear during the spring and summer months, the scallops' gonad will develop more slowly.

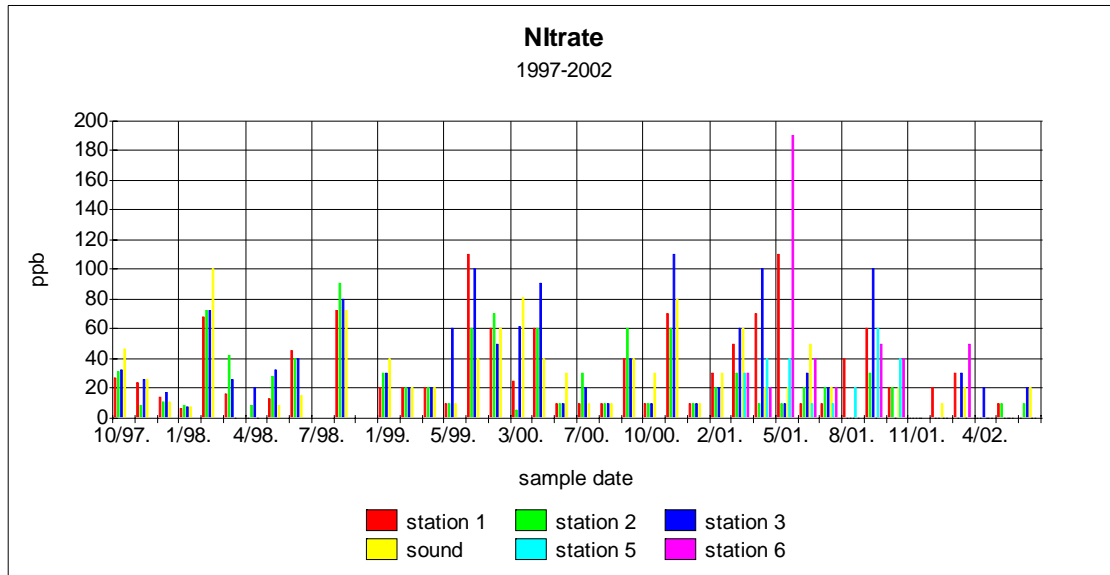
The abundance of food is critical to gonad development. Gonad growth is linked to peak phytoplankton abundance and temperature. If a scallop is starved at the optimal temperature for gonad development, the gonad will not grow. The energy obtained from phytoplankton is used for maturation and reproduction during the months of April through July. Energy reserves are located in the digestive gland and abductor muscle. Temperature and maturation regulates the rate of energy transferred into gonad development. Bay scallops are dependent on phytoplankton abundance until 9 months old. After the gonad is developed at 10 months, starvation will not affect spawning but temperature will.

Generally, we observe diatoms in the fall and winter and dinoflagellates in the late spring and summer. Both dinoflagellates and diatom species are present in the water. Water chemistry, light, and temperature dictate which species becomes dominant throughout the year.

Productivity Cycle

In the years of 1994-1998, a pattern of alternating good and poor water clarity was observed. During January, the harbor contained low nutrient levels; moderate phytoplankton concentrations; and good water clarity. In February, a diatom bloom occurred simultaneously with elevated nitrate concentrations. This bloom has originated from the Sound and reduced water clarity. Following the bloom, nitrate concentrations and phytoplankton concentrations decrease to very low levels and water clarity is high in March and April. During May through September, nitrate and phosphorus concentrations increase; dinoflagellates bloom; and water clarity is decreased. Again, dinoflagellates are blooming as the same time the gonad is trying to develop. Scallops obtain their nutrition from diatoms. If the quality of food is

compromised because of too many nutrients, the development of the gonad will be retarded. The water clears again in October. The second scallop spawning event occurs generally in September or October. Since diatoms are dominant in the fall, these scallops have plenty to eat while the water temperature remains over 45F.



Nitrate

Nitrogen occurs in three major forms in aquatic systems (ammonia, nitrate and organic compounds). Nitrite is a fourth form; but due to its instability, it exists for very short periods of time during the conversion between other forms. Nitrate and ammonia are readily available for uptakes by plants. Both forms can cause toxicity problems at high concentrations.

Nitrogen is limited in Nantucket Harbor and limits primary production of aquatic plants. As nitrate levels increase, phytoplankton, macroalgae (seaweed), epiphytes (plants that attach) reproduce. The greater the concentration of nitrogen in the water column, the more plants will grow. When these plants die, bacteria use dissolved oxygen from the water column to decompose the organic plant matter. This can result in ecosystem stress, due to oxygen depletion.

Nitrogen Loading

Nitrogen is limited in salt water systems. Nitrogen concentrations dictate the productivity of aquatic plant life ranging from phytoplankton to seaweed. Development in the watershed leads to increases nitrogen inputs from the land to the waterbodies. Eutrophication, too many nutrients, cause lower water quality, phytoplankton blooms, and anoxia. **Since nitrogen is limited in Nantucket Harbor, nitrogen concentrations entering the harbor through the watershed dictates the rate of eutrophication.**

The following information has been summarized by the finding in "Land-derived nitrogen loading to Nantucket Harbor, May 2000" report by Valiela et al. Nitrogen loads in the Nantucket Harbor watershed appear to be modest since eelgrass is still present in the Harbor.

For each of the 14 subwatersheds, nitrogen loads were calculated. Nitrogen is derived from septic systems, lawn fertilizer, atmospheric deposition, agriculture, etc. The estimates of the nitrogen loads from atmospheric deposition, septic wastewater, and fertilizer use, delivered through different land cover types to the watershed and to Nantucket Harbor were calculated.

In the watershed for Nantucket Harbor, only 13% of the buildings dispose of wastewater through septic systems, and as a result, water nitrogen contributes a relatively small percentage (15%) of the total land derived nitrogen load. Nitrogen from atmospheric deposition input 62% into Nantucket Harbor. Fertilizer application to lawns is the major source of fertilizer nitrogen to the watershed and Nantucket Harbor comprising of 22% of the nitrogen load.

To manage future increases of nitrogen loads, it would be desirable to maintain areas of natural vegetation; this would prevent atmospheric nitrogen from increasing and reaching Nantucket Harbor. Application of lawn fertilizer should be minimized and the addition of new septic systems should be limited.

The estimated nitrogen load, on a per unit area basis to Nantucket Harbor is much lower than loads to other Cape Cod estuaries. This is due in part to the small percentage of houses with contributing septic systems with the Nantucket Harbor watershed. For example, Hamblin Pond, Jehu Pond, Green Pond Quashnet River and Childs River have an average building density of 1.2 buildings per hectare of watershed, compared to 0.2 in the Nantucket Harbor watershed. If building density increases in Nantucket Harbor watershed, the Nitrogen load to the harbor will increase from wastewater inputs and fertilizer use on lawns.

Nitrogen/Phosphorus Ratio

It is important to determine which nutrient may be in shortest supply in relation to the needs of plants (phytoplankton or rooted aquatic plants). It is the relative abundance of this nutrient which will control or "limit" primary production in the water body. An increase in the amount of the limiting nutrient should result in a proportional amount of additional plant production, and vice versa. This limiting nutrient concept or "Law of the Minimum" is an important principle because it explains the response of a waterbody to increases in watershed pollution, but also indicates the priority of which elements should be reduced to effect a change in the harbor conditions.

Nitrogen and phosphorus both provide the food source for phytoplankton growth. The ratio of nitrogen to phosphorus is necessary to determine which is the limited nutrient. Phytoplankton requires approximately 16 parts of nitrogen to 1 part of phosphorus to grow. Nitrogen is considered "limited" in Nantucket Harbor.

The concentration of nitrogen in the marine environment dictates phytoplankton production. However, an overabundance of either nutrient will result in a shift of phytoplankton species population. Nine streams and four Nantucket Harbor sites were sampled for water quality parameters during 2000. Stream 3 contained the greatest concentrations of nitrates in 2000 and 2001. The streams contained high levels of organic nitrogen. Nitrogen is entering the harbor and increasing the nitrogen/phosphorus ratio. The observed N/P ratio in 1993 was recorded at approximately 3. In 2001, the N/P ratio has increased in some area to 10. If Nantucket Sound (station 4) is used as the background, nitrogen is being added to harbor through the watershed. Nitrogen is being removed from the harbor with each tidal cycle. A higher N/P ratio was observed in the spring and fall of 2001.

Phosphorus is also entering Nantucket Harbor in significant amounts. Stream 4, which flows from the bogs into Polpis East contained high levels of phosphorus in April (0.253 ug/sec). Low levels of dissolved oxygen in August in Polpis East could have recycled phosphorus bound to sediment to be released into the water column. Phosphorus was recorded at 0.30 mg/l in Polpis East in September.

Nutrient ratios alone do not provide conclusive proof of limiting factors. Other considerations such as light, the movements of water, internal recycling or microbial processes are taken into account. However, nitrogen and phosphorus concentrations are increasing over time. The following graph is data collected from 2001.

Phosphorus

Phosphorus is initially made available to living organisms through the weathering of rocks. Phosphorus is found in the environment as a form of soluble phosphate ions. Phosphate, which is applied to a lawn as fertilizer, becomes bound to soil particles. Phosphorus is a major eutrophication contaminant in surface water. Principal loading is due soil erosion.

Phosphorus levels exceeded 0.050 mg/l indicating enriched conditions. To date, phosphorus concentrations have exceeded these levels on more than one occasion since 1998. Phosphorus concentrations are rising with more frequency at more sample stations.

In June 2001 at station 6 (Polpis East), phosphorus levels were 0.146 mg/l. In September 2001, all harbor stations exceeded enriched conditions ranging from 0.064 mg/l to 0.297 mg/l. (Reference TP Chart)

The leaching field effluents of a conventional septic system contain 40 to 60 mg/l of nitrogen and 8 to 38 mg/l of phosphorus. Effluents contain a large number of pathogenic bacteria and viruses. Virus inactivation times in groundwater are approximately 120-200 days.

Phosphorus is detected in low concentration during the winter. Phosphorus increases in the spring, early summer and fall. During the early summer, the mooring field and Quaise basin sites increased in phosphorus concentrations as a result of both Nantucket Sound and stream flow. The phosphorus in the head of the harbor is most likely a result of stream flow only. Head of the harbor increases gradually in phosphorus throughout the spring, summer, and fall.

In Quaise Basin (station 2) and head of the harbor (station 3), the stable concentration of phosphorus may be the result of septic systems. Conversely, spikes of phosphorus measured in the summer and fall are most probably the result of fertilizer application. As stream velocity increase in the spring, the result is increased sedimentation. Phosphorus remains bound to the sediments until carried by storm water or ground water flows. The reduction in phosphorus concentration during the end of July and August correlate with groundwater flow.

Eelgrass

Eelgrass is important bay scallop habitat. Eelgrass is used to gage water quality conditions in estuaries. Eelgrass tends to dominate shallow temperate waters exposed to low nutrients inputs. Eelgrass can store substantial amounts of nitrogen in their thick leaves, stems, and rhizomes for translocation. This property allows eelgrass to characterize shallow waters where nutrient and competition are low.

Eelgrass is gradually declining in Nantucket Harbor. The reduction of eelgrass blades per square meter is most probably a result of eutrophication. Eelgrass surveys conducted in 1989, 1997, and 1999 depict eelgrass beds becoming smaller and more fragmented while algae, codium, and "red wool" are increasing in density and area.

In Nantucket Harbor, this distribution of eelgrass will extend down to the 8ft contour line in most of the Nantucket Harbor with the exception of Wauwinet. In the Head of the Harbor, there is light restrictions and reduced water quality which prohibit eelgrass from extending down past 6ft in most cases. During periods of high water clarity, 10% of surface light reaches approximately 20ft below the surface. During periods of low clarity, 10% of light reaches only 8 ft below the surface.

Nantucket Harbor experiences two periods of poor water clarity. Harbor water is turbid in January through March and June through August. During these times, the Head of the Harbor has the poorest clarity, lowest oxygen, and the greatest internal nutrient loading. However, since light penetration is limited for only a portion of the growing season deeper eelgrass beds can occur. Eelgrass below 6ft may be stressed with poor re-growth following a disturbance (i.e. dredging, boat scaring).

Contrarily, macroalgae (i.e. Polysiphonia, codium) and phytoplankton species (i.e. dinoflagellates) in shallow temperate estuaries tend to nutrient limited rather than light limited. Increased availability of nutrients prompts the growth of benthic macroalgae and epiphytic (free floating or attached) algae on the eelgrass blade surfaces. These epiphytes block out light causing detriment to eelgrass plants. The eelgrass is also subject to shading by the unattached benthic algae, epiphytes, and phytoplankton.

Increased nitrogen loads add to the physiological advantages of macroalgae over eelgrass. This increases the chance of that macroalgae will shade and eventually replace eelgrasses as the dominant macroproducer. Progressive eutrophication (nutrient loading) of shallow water generally increases benthic macroalgae (bottom seaweed) production, and these alterations are soon followed by reduction of eelgrass meadows and bay scallop habitat.